Using fish diets as ecosystem indicators:

Are fish feeding down the food web on Georges Bank?

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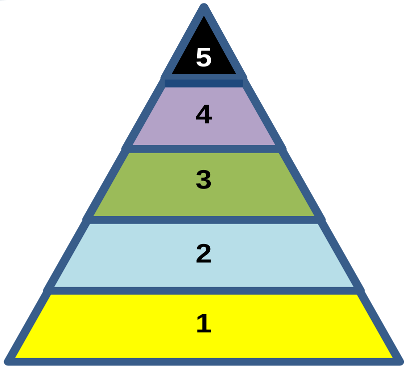
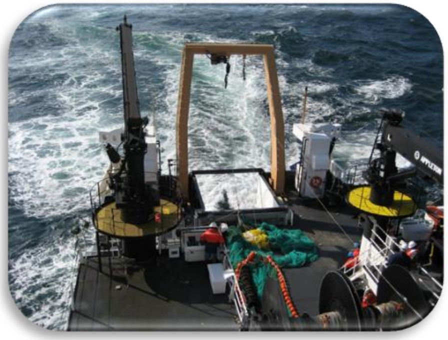


Major Objectives

1. Develop time series of ecosystem mean trophic level (MTL) from fish diets (21 species) and survey trawl data for Georges Bank of the northeast U.S. continental shelf.
2. Identify common trends in MTL among fish diets and survey data.
3. Answer the question: Are fish feeding down the food web?



Rationale

1. Global concern for decrease in MTL derived from fisheries catches (i.e. Fishing Down Food Web).
2. Suggested that catch MTL represents ecosystem MTL; thus decreases imply global reduction in marine biodiversity.
3. Imperative to identify suitable ecosystem indicators for monitoring biodiversity given potential disruptions from large-scale forces.

Rationale

4. Addressing the suitability of catch MTL as an indicator, we can explore this topic with fish diets from opportunistic generalists spanning the benthos to mid-water environments on Georges Bank.

5. Highly debated topic and why we're here today.

Available Data

1. Fish biomass per tow from seasonal bottom trawl surveys on Georges Bank, 1963-2012.

2. Diet data for Georges Bank fish community (21 species of groundfish, flounders, pelagics, and elasmobranchs) from seasonal bottom trawl surveys, 1973-2012.

Predators

Groundfish

Atlantic cod (*Gadus morhua)*
Goosefish (*Lophius americanus)*
Haddock (*Melanogrammus aeglefinus)*
Ocean pout (*Zoarces americanus)*
Pollock (*Pollachius virens)*
Red hake (*Urophycis chuss)*
Silver hake (*Merluccius bilinearis)*
White hake (*Urophycis tenuis)*

Pelagics

Atlantic herring (*Clupea harengus)*
Atlantic mackerel (*Scomber scombrus)*

Elasmobranchs

Spiny dogfish (*Squalus acanthias)*
Thorny skate (*Amblyraja radiata)*
Winter skate (*Leucoraja ocellata)*

Flounders

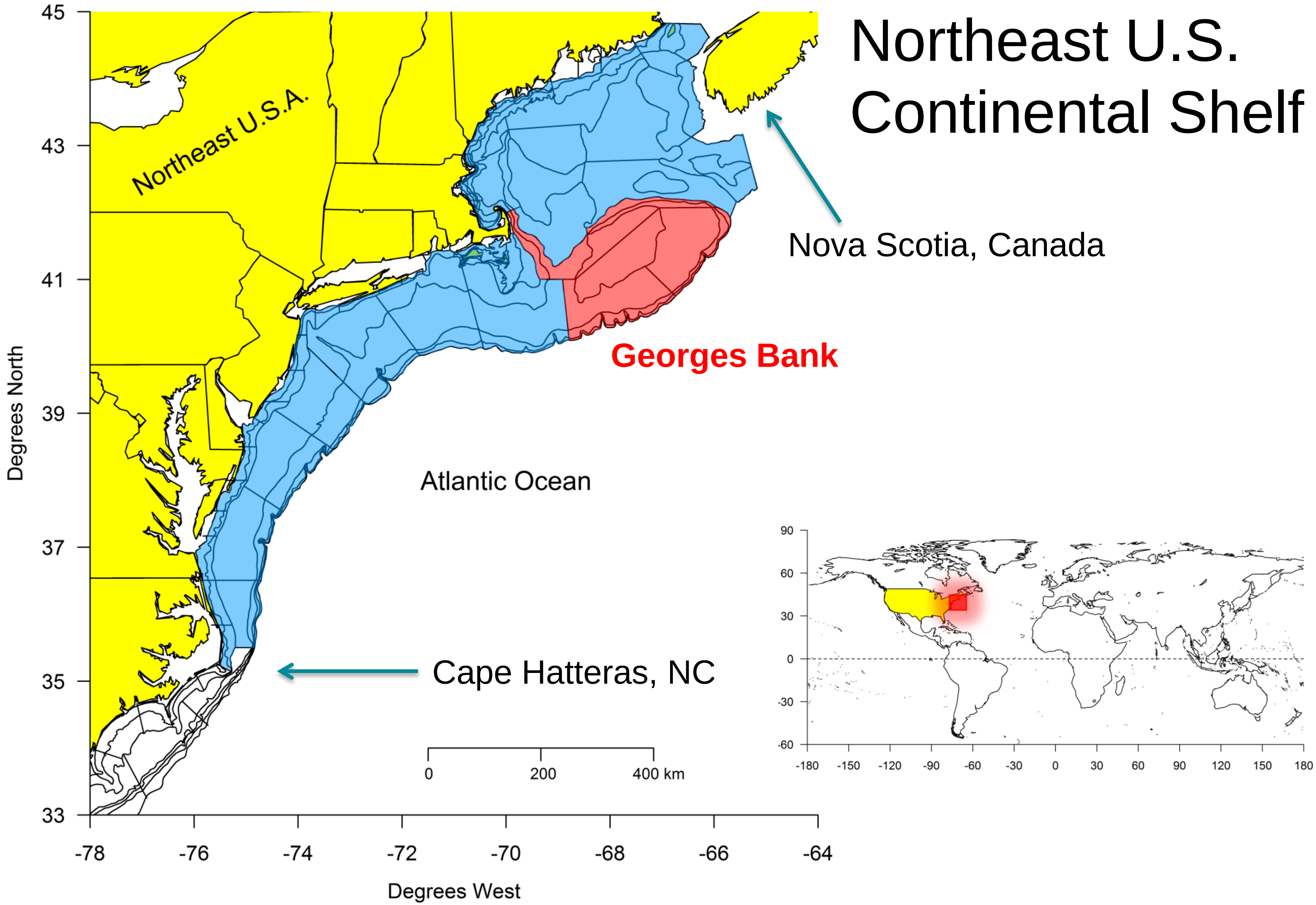
American plaice (*Hippoglossoides platessoides)*
4-spot flounder (*Paralichthys oblongus)*
Windowpane flounder (*Scophthalmus aquosus)*
Winter flounder (*Pseudopleuronectes americanus)*
Witch flounder (*Glyptocephalus cynoglossus)*
Yellowtail flounder (*Limanda ferruginea)*

Others

Longhorn sculpin (*Myoxocephalus octodecemspinosus)*

Sea raven (*Hemitripterus americanus)*

Northeast U.S. Continental Shelf



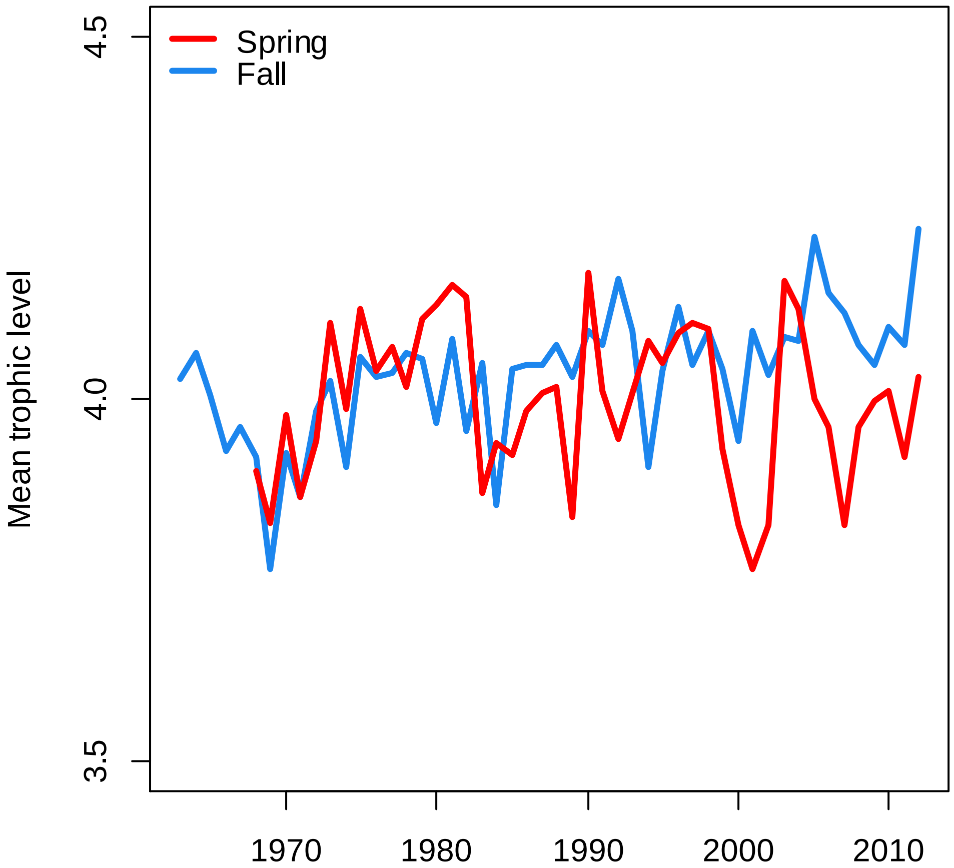
Mean Trophic Level (*MTL*$_y$)

$$MTL_y = \frac{\sum_i (TL_i \cdot Y_{iy})}{\sum_i Y_{iy}}$$

TL_i = Trophic level per species group *i.*
Y_{iy} = Survey catch or prey biomass of species *i* in year *y.*

1. Annual average *TL* weighted by species group biomass from survey catches or fish diets.
2. *TL* of species groups derived with Ecopath (e.g. demersals-omnivores, small pelagics-commercial; Link et al. 2008).

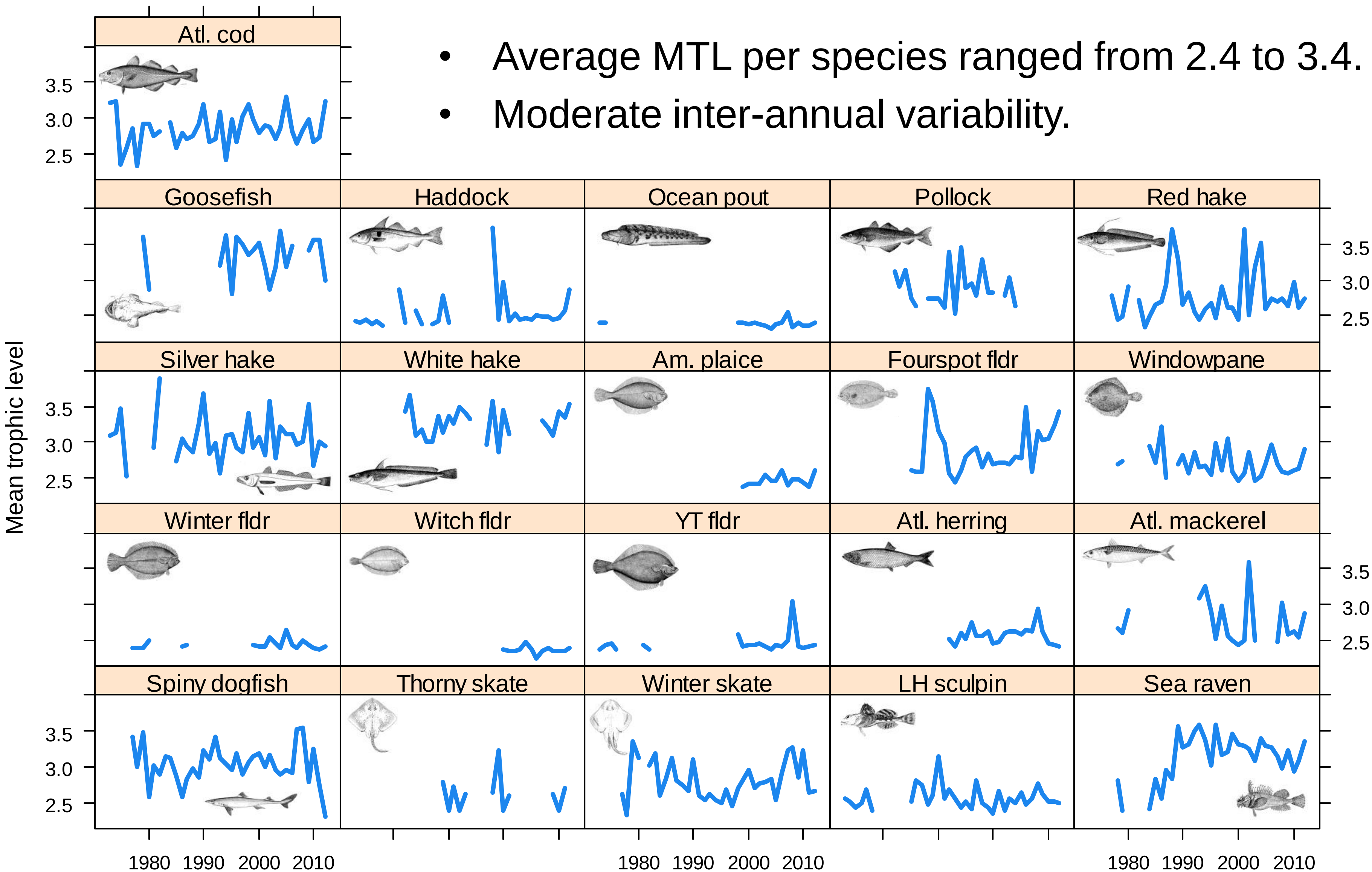
Survey Mean Trophic Level



- Average annual MTL per season was 4.03 (spring) and 4.00 (fall).
- Minor inter-annual variability.
- Final MTL time series taken as an annual average of spring and fall data.

Diet Mean Trophic Level

- Average MTL per species ranged from 2.4 to 3.4.
- Moderate inter-annual variability.



Time Series Modeling

- Multivariate autoregressive state-space models

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ \vdots \\ y_{22} \end{bmatrix} = \begin{bmatrix} Z_{1,1} & Z_{1,2} & Z_{1,3} & Z_{1,4} & Z_{1,5} \\ Z_{2,1} & Z_{2,2} & Z_{2,3} & Z_{2,4} & Z_{2,5} \\ Z_{3,1} & Z_{3,2} & Z_{3,3} & Z_{3,4} & Z_{3,5} \\ Z_{4,1} & Z_{4,2} & Z_{4,3} & Z_{4,4} & Z_{4,5} \\ Z_{5,1} & Z_{5,2} & Z_{5,3} & Z_{5,4} & Z_{5,5} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{22,1} & Z_{22,2} & Z_{22,3} & Z_{22,4} & Z_{22,5} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} + \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ \vdots \\ a_{22} \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ \vdots \\ v_{22} \end{bmatrix}$$

$$\begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_{22} \end{bmatrix} \sim \mathbf{MVN}\left(\begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}, \begin{bmatrix} R_{1,1} & R_{1,2} & \dots & R_{1,22} \\ R_{2,1} & R_{2,2} & \cdots & R_{2,22} \\ \vdots & \vdots & \ddots & \vdots \\ R_{22,1} & R_{22,2} & \dots & R_{22,22} \end{bmatrix} \right)$$

- Non-stationary data
- Missing data
- Dynamic factor analysis
- Model process and observation error separately
- EM algorithm
- Trend based on random walk

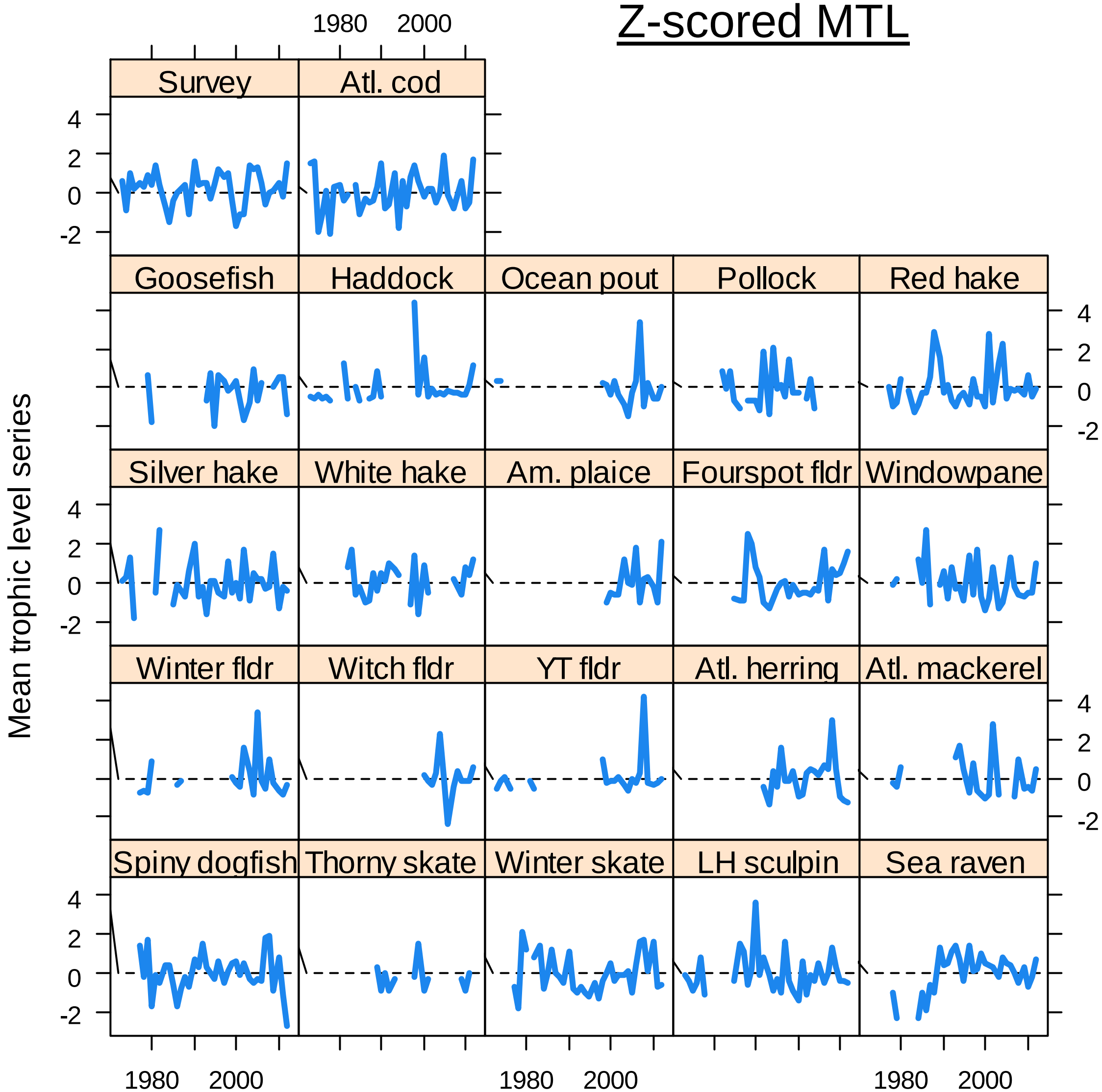
Identifying Trends

Model Selection

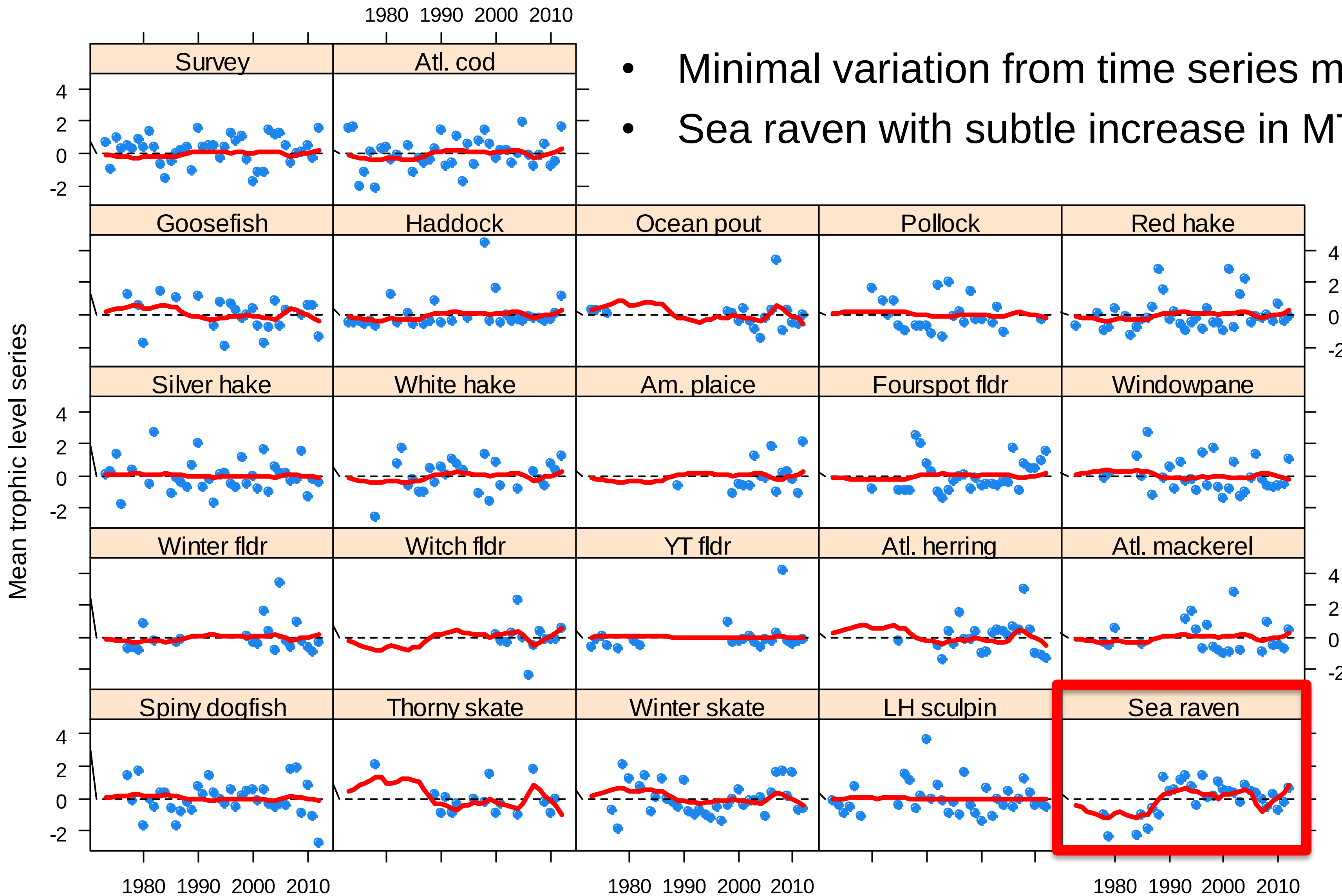
R = covariance matrix structure;
m = number of trends;
AICc = selection measure.

Model	R	m	AICc
1	diagonal and equal	1	1696.5
2	diagonal and equal	2	1730.9
6	diagonal and unequal	1	1734.1
3	diagonal and equal	3	1767.1
7	diagonal and unequal	2	1770.8
4	diagonal and equal	4	1801.3
8	diagonal and unequal	3	1807.3
9	diagonal and unequal	4	1840.0
5	diagonal and equal	5	1843.9
10	diagonal and unequal	5	1877.1

Z-scored MTL



Modeling Mean Trophic Level



- Minimal variation from time series means.
- Sea raven with subtle increase in MTL?


D. Chevrier

Conclusions

1. Contrary to global fisheries catch MTL, modeled diet and survey catch on Georges Bank has not shifted dramatically over the past 4+ decades.

2. One common pattern among diet and survey catch MTL was identified, suggesting these time series are time-invariant.

Discussion

1. Identifying actual trends in ecosystem health is challenging. Diets from opportunistic generalists shed a novel light on monitoring ecosystem change.

2. The collective diet stability and feeding strategies of these predators on Georges Bank may strengthen ecosystem resilience.


A. Miller

Discussion

3. Maintaining long-term biodiversity remains an intriguing challenge. Specific to fisheries, the pivotal roles of targeted species, and the demands on communities and various habitats surely test ecosystem stability.

4. With many large-scale drivers present, applying ecological interactions with the monitoring and conservation of marine communities and fish stocks is highly advantageous.

Thank you!

- Many survey personnel for data collection.
- Symposium conveners and participants.

A. O'brien